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Transmitted herewith for filing is the patent application of

Inventor(s): **Sergey LAMANSKY and Mark E. THOMPSON**

For : **ORGANOMETALLIC PLATINUM COMPLEXES FOR
PHOSPHORESCENCE BASED ORGANIC LIGHT EMITTING
DEVICES**

Enclosed are:

1. 12 sheets of specification, 1 sheet of claims, and 1 sheet of abstract.
2. 8 sheets of drawings.
3. Declaration (unexecuted).
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organometallic platinum complexes
for phosphorescence based
organic light emitting devices

ORGANOMETALLIC PLATINUM COMPLEXES FOR PHOSPHORESCENCE BASED ORGANIC LIGHT EMITTING DEVICES

FIELD OF THE INVENTION

5 The present invention is directed to phosphorescence based organic light emitting devices that have improved electroluminescent characteristics.

BACKGROUND OF THE INVENTION

10 The technology of organic light emitting diodes (OLEDs) is undergoing rapid development. OLEDs originally utilized the electroluminescence produced from electrically excited molecules that emitted light from their singlet states. Such radiative emission from a singlet excited state is referred to as fluorescence. More recent work has demonstrated that higher power efficiency OLEDs can be made using molecules that emit light from their triplet state, defined as phosphorescence.

15 Such electrophosphorescence makes it possible for phosphorescent OLEDs to have substantially higher quantum efficiencies than are possible for OLEDs that only produce fluorescence. This is based on the understanding that the excitons created in an OLED are produced, according to simple statistical arguments as well as experimental measurements, approximately 75% as triplet excitons and 25% as singlet excitons. The triplet excitons more readily transfer their energy to triplet excited states that can produce phosphorescence
20 whereas the singlet excitons typically transfer their energy to singlet excited states that can produce fluorescence. Since the lowest emissive singlet excited state of an organic molecule is typically at a slightly higher energy than the lowest triplet excited state, the singlet excited state may relax, by an intersystem crossing process, to the emissive triplet excited state. This means that all the exciton excitation energy may be converted into triplet state excitation
25 energy, which then becomes available as phosphorescent emission. Thus, electrophosphorescent OLEDs have a theoretical quantum efficiency of 100%, since all the exciton excitation energy can become available as electrophosphorescence.

As a consequence, since the discovery that phosphorescent materials could be used in an OLED, Baldo *et al.*, "Highly Efficient Phosphorescent Emission from Organic Electroluminescent Devices", *Nature*, vol. 395, 151-154, 1998, there is now much interest in finding more efficient electrophosphorescent materials.

Typically phosphorescent emission from organic molecules is less common than fluorescent emission. However, phosphorescence can be observed from organic molecules under an appropriate set of conditions. Organic molecules coordinated to lanthanide elements often phosphoresce from excited states localized on the lanthanide metal. The europium diketonate complexes illustrate one group of these types of species. Organic phosphorescence is also often observed in molecules containing heteroatoms with unshared pairs of electrons at very low temperatures. Benzophenone and 2,2'-bipyridine are such molecules. Phosphorescence can be enhanced over fluorescence is by confining, preferably through bonding, the organic molecule in close proximity to an atom of high atomic number. This phenomenon, called the heavy atom effect, is created by a mechanism known as spin-orbit coupling. A related phosphorescent transition is a metal-to-ligand charge transfer (MLCT) that is observed in molecules such as tris(2-phenylpyridine)iridium(III).

However, molecules that phosphoresce from MLCT states typically emit light that is of lower energy than that observed from the unbound organic ligand. This lowering of emission energy makes it difficult to develop organic molecules that phosphoresce in the technologically useful blue and green colors of the visible spectrum where the unperturbed phosphorescence typically occurs.

It would be desirable if more efficient electrophosphorescent materials could be found, particularly materials that produce their emission in the blue region of the spectrum.

SUMMARY OF THE INVENTION

The present invention is directed to organic light emitting devices, and methods of fabricating the same, that involve using emissive organometallic compounds that produce improved electroluminescence.

Specific embodiments of the present invention are directed to OLEDs using emissive organometallic compounds that produce improved electrophosphorescence in the blue region of the visible spectrum.

The present invention is directed, in addition, to a method of selecting organometallic compounds that have improved electroluminescent properties, for example, in the blue region of the visible spectrum.

The organometallic compounds of the present invention include, in particular, compounds having a metal atom bound to a single carbon-coordination ligand, wherein the carbon-coordination ligand is a mono-anionic carbon-coordination ligand.

A carbon-coordination ligand is a ligand that is bound to the metal atom via a carbon-metal bond. In view of what one skilled in the art might view as a strict definition of organometallic compounds, such as described in Inorganic Chemistry, by Gary L. Miessler and Donald A. Tarr, 2nd edition, Prentice Hall, 1999, the compounds of the present invention are referred to herein as organometallic compounds since these compounds include a metal-carbon bond.

The preferred metals of the present invention are metals that can provide strong spin-orbit coupling of the metal atoms with the carbon-coordination ligand. Such metals include, in particular, the heavy metals having an atomic number of at least 72. Particularly preferred metals include Pt, Ir and Au, with the most preferred being Pt.

The organometallic compounds of the present invention have a single carbon-coordination ligand wherein the single carbon-coordination ligand is a mono-anionic ligand. In particular, the metal atom is bound to only one carbon atom of the carbon-coordination ligand. Thus, while the organometallic compounds that are used in the OLEDs of the present invention may typically include more than one ligand, only one ligand is a carbon-coordination ligand. Thus, the organometallic compounds of the present invention include only one carbon-metal bond.

The carbon-coordination ligand is preferably selected from those ligands that exhibit strong charge transfer absorption characteristics, for example, a molar absorptivity of at least 1,000 L/mole-cm, preferably, at least about 2,000-4,000 L/mole-cm. Such absorption bands involve transfer of electrons from molecular orbitals that are primarily ligand in character to

orbitals that are primarily metal in character or, alternatively, from orbitals that are primarily metal in character to molecular orbitals that are primarily ligand in character. Miessler and Tarr. Such an excitation mechanism results in a charge transfer transition that may be designated as a ligand-to-metal charge transfer (LMCT) or as a metal-to-ligand charge transfer (MLCT), respectively. The former may be characterized as a partial reduction of the metal atom and the latter as a partial oxidation of the metal atom.

Selection of a carbon-coordination ligand to give a high molar absorptivity of the organometallic compound results in an organometallic compound that is capable of providing highly efficient electroluminescence when used in an OLED. However, rather than functioning as strongly absorbing species in the OLED, such organometallic compounds have highly emissive excited states that are produced when a voltage is applied across the OLED. The high molar absorptivities of such ligands may be used to select ligands that produce highly efficient electroluminescence in an OLED. Such ligands may be selected to have empty pi-symmetry orbitals on the ligands that become acceptor orbitals upon absorption of light.

In the preferred embodiments of the present invention, the ligand is selected, in particular, so as to give a strong metal-to-ligand charge transfer (MLCT) absorption band. Such ligands are selected to have empty anti-bonding π^* orbitals on the ligands that become acceptor orbitals upon absorption of light. As representative embodiments of the present invention, the carbon-coordination ligand may be selected from the class of materials such as described, for example, in Comprehensive Coordination Chemistry, Vols. 1-7, G. Wilkinson, Ed., Pergamon Press, 1987.

In addition to being bound to a single mono-anionic carbon-coordination ligand, the metal atom of the organometallic compounds of the present invention is also bound to one or more additional ligands, each of which are all non-carbon-coordination ligands. A non-carbon-coordination ligand is one that does not form any metal-carbon bonds with the metal atom of the organometallic compound. For the preferred embodiments of the present invention for which a metal to ligand charge transfer complex (MLCT) is employed, the non-carbon-coordination ligands are preferably ligands having a strong electrophilic character such that the ligands draw electrons away from the metal atom. Representative non-carbon-coordination ligands may also be selected, for example, from Comprehensive Coordination Chemistry, Vols. 1-7, G. Wilkinson, Ed., Pergamon Press, 1987.

Without intending to be limited to the theory of how the present invention works, it is believed that the improved electroluminescent properties that are observed for the OLEDs of the present invention may be attributed to a combination of factors. For example, it is believed that selection of heavy metals that are capable of forming metal-to-ligand charge transfer (MLCT) states with carbon-coordination ligands that have empty π^* orbitals, such phosphorescent materials produce highly efficient electrophosphorescent OLEDs. The electroluminescence from representative organometallic compounds of the present invention shows a vibronic fine structure that indicates that the emission is from an excited state that has a wave function represented by a mixture of the MLCT state of the organometallic compound and the excited triplet state of the carbon-coordination ligand. Since the radiative emission is from a triplet excited state, the emission is referred to as phosphorescence.

It is further believed a higher energy radiative emission may be achieved by including electron-withdrawing groups on the carbon-coordination ligand and/or by selecting the non-carbon-coordination ligand to have a strong electron withdrawing character. Without being limited to the precise theory of how the higher energy radiative emissive may be achieved, it is believed that the electron-withdrawing groups tend to remove electron density from the highest occupied molecular orbitals (HOMO) that include the ligand and the metal atom, thus altering the relative energy levels of the ground state and the excited state such that the overall MLCT transition energy from the ground state to the excited state increases. The preferred organometallic compounds of the present invention include, thus, strong electron-withdrawing groups on the carbon-coordination ligand and/or non-carbon-coordination ligands having a strong electron-withdrawing character.

Another aspect of the present invention relates to the discovery that OLEDs incorporating emissive organometallic compounds having a single mono-anionic carbon-coordination ligand have substantially higher external quantum efficiencies than compound with bis-substituted carbon-coordination ligands. For example, for the compound having the chemical structure $[(ppy)Pt(acac)]$ was found to produce strong photophosphorescence at room temperature. In contrast, a compound having the structure $[Pt(ppy)_2]$ was found not to produce any visible photophosphoresce at room temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the chemical structures of representative organometallic compounds described herein.

Figure 2 shows the emission spectrum of both Pt(ppy)₂ and Pt(ppy)₂Br₂. The former gives green emission, partly from MLCT transitions, and the latter gives blue emission, predominantly from a triplet π - π^* transition. The structure observed for the Pt(ppy)₂Br₂ spectrum is consistent with ligand-centered emission. The luminescent lifetimes for the two complexes are 4 and 150 microseconds.

Figure 3 is a plot showing the emission spectra of (ppy)AuCl₂ and (ppy)Au(2,2'-biphenylene). Both emit from ligand triplet π - π^* transitions.

Figure 4 is a CIE diagram providing the coordinates of (C-N)Pt(acac) complexes. All coordinates are based on solution photoluminescent measurements except for 4,5-F₂ppy-EL, which corresponds to the electroluminescent spectrum. The Ir(ppy)₃ is an electroluminescent spectrum as well.

Figure 5 is a plot depicting the photoluminescent emission spectra of (4,6-F₂ppy)Pt(acac) at room temperature (RT) and at 77 K. Also shown are the excitation spectra taken at 77 K and the absorbance spectra taken at room temperature for the same complex.

Figure 6 illustrates the normalized photoluminescent emission spectra of (ppy)Pt(acac), (4,5 dfppy)Pt(acac), and (4,5 dfppy)Pt(pico).

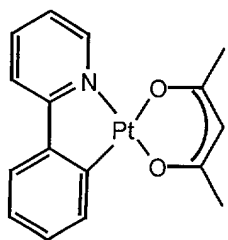
Figure 7 illustrates the normalized photoluminescent emission spectra of typPy(acac), bzqPt(acac), and btpPt(acac).

Figure 8 illustrates the normalized electroluminescent emission spectra for OLEDs prepared with (2-(4,5-F₂phenyl)pyridinato)platinum(acetyl acetate). The OLEDs had a ITO/PVK-PBD-dopant/Alq₃/Mg-Ag layer structure. The PVK layer was deposited as a single, homogeneous layer by spin coating. PVK = polyvinylcarbazole and PBD = (4-biphenyl)(4-tertbutyl)oxiadiazole. The Alq₃ and Mg-Ag layers were deposited by thermal evaporation. The OLED had an external efficiency of 1.3 % and a turn on voltage of 5 Volts. The spectra of the EL output and as well as the PL signal are shown.

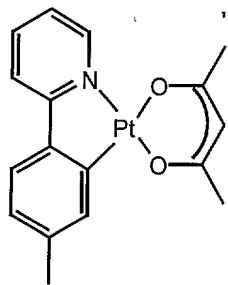
DETAILED DESCRIPTION OF THE INVENTION

The present disclosure is aimed at a new class of platinum complexes, which give efficient phosphorescence. The representative complexes have a single organometallic ligand (cyclometallated) and a bidentate coordination ligand (such as acetylacetonate). Several examples of these complexes are given below along with their spectra. The emission spectra from these complexes show vibronic fine structure, consistent with strong ligand $\pi - \pi^*$ character in the phosphorescent transition. Strong ligand $\pi - \pi^*$ character is also consistent with the fact that the emission energy is strongly dependent on the identity of the ligand, as shown in the spectra shown below. Emission from these complexes results from a mixture of metal to ligand charge transfer (MLCT) and ligand based transitions. The MLCT is critical to enhance the efficiency of intersystem crossing and phosphorescence. The emission is dominated by the cyclometallated ligand and the MLCT between the Pt ion and that ligand. The emission spectrum is only slightly affected by changing the acetylacetonate ligand (acac) to a picolinic acid (pico), as shown for the (ppy)PtX complexes below. This minor shift most likely occurs due to a shift in the Pt based HOMO level by the pico ligand, leading to a red shift in the MLCT and a corresponding red shift in the emission spectrum.

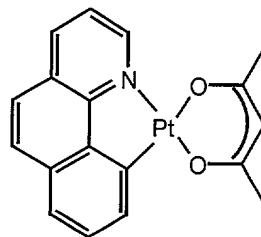
One of these complexes, i.e. (2-(4,5-F₂-phenyl)pyridinato)Pt(acetylacetonate), was used as a phosphorescent dopant in a polymer OLED and gave an emission spectrum identical to the photoluminescence spectrum and an external quantum efficiency of 1.3%.



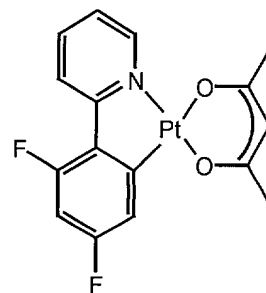
(ppy)Pt(acac)



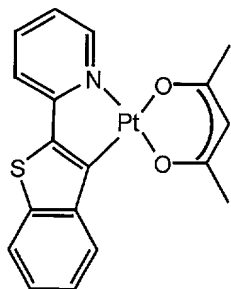
(tpy)Pt(acac)



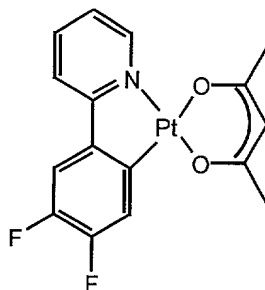
(bzq)Pt(acac)



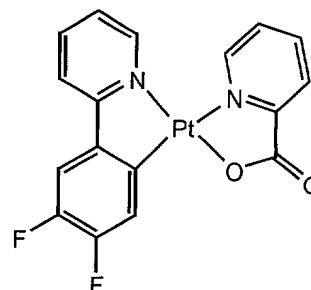
(4,6-F₂ppy)Pt(acac)



(btp)Pt(acac)



(4,5-F₂ppy)Pt(acac)



(4,5-F₂ppy)Pt(pico)

As representative electrophosphorescent compounds of the present invention, the carbon-coordination ligand forms a cyclometallated ring that includes the organometallic carbon-metal bond and a dative bond between the metal atom and a nitrogen, sulfur or oxygen group, for example, Pt(II)-(2-phenylpyridinato-N,C^{2'})(acetyl acetate), herein referred to as Pt(ppy)(acac) or (ppy)Pt(acac). The carbon atom that is bound to the metal may be present as part of a substituted or unsubstituted, saturated hydrocarbon; a substituted or unsubstituted, aromatic system, for example, phenylene or naphthalene compounds; or a substituted or unsubstituted heterocyclic system, which might include, for example, substituted or unsubstituted thiophenes, furans, pyridines and pyrroles. The group in the cyclometallated ring that forms a dative bond with the metal atom may be independently selected also to include a substituted or unsubstituted, saturated hydrocarbon; a substituted or unsubstituted, aromatic system, for example, phenylene or naphthalene compounds; or a substituted or unsubstituted heterocyclic system, which might include, for example, thiophenes, furans, pyridines and pyrroles.

EXAMPLES OF THE INVENTION

All procedures involving K_2PtCl_4 or any other Pt species were carried out in inert gas atmosphere in spite of the air stability of the compounds, the main concern being their oxidative stability and stability of intermediate complexes at high temperatures used in the reactions. NMR spectra were recorded on Bruker AMX 360 MHz or 500 MHz instruments unless specified otherwise. Solid probe MS spectra were taken with Hewlett Packard GC/MS instrument with electron impact ionization and model 5873 mass sensitive detector. High resolution mass spectrometry was done at Frik Chem Laboratories at Princeton University. Elemental analysis data was recorded at the Microanalysis Laboratory at the University of Illinois, Urbana-Champaign.

Pt(II) μ -chlorobridged dimers of the structure $[Pt(C-N)(\mu-Cl)_2Pt(C-N)]$ containing cyclometalated carbon,nitrogen ligands (C,N) used in the study were prepared according to Cave G.W.V., Fanizzi F.P., Deeth R.J., Errington W., Rourke J.P., Organometallics 2000, 19, 1355.

Platinum(II) (2-phenylpyridinato- N,C^2') (acetyl acetate) $[Pt(ppy)(acac)]$. 100 mg of $Pt(ppy)(\mu-Cl)_2Pt(ppy)$ dimer, 25 mg of 2,4-pentanedione and 85 mg of anhydrous sodium carbonate were refluxed at 100 °C in 8 ml of 2-ethoxyethanol under inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and filtration yielded crude product that after drying and flash chromatography (silica/dichloromethane) gave bright yellow-green solid (36% yield). 1H NMR (360 MHz, acetone- d_6), ppm: 9.00 (d, 1H, J 5.8Hz), 8.02 (dt, 1H, J 1.6, 7.4Hz), 7.89 (d, 1H, J 7.9Hz), 7.57 (dd, 1H, J 1.6, 7.4Hz), 7.51 (dd, 1H, J 1.6, 7.9Hz), 7.32 (dt, 1H, J 1.6, 6.8Hz), 7.11 (dt, 1H, J 1.6, 7.9Hz), 7.04 (dt, 1H, J 1.6, 7.4Hz), 5.55 (s, 1H), 1.96 (s, 3H), 1.95 (s, 3H). See Figure 4, compound number 5. See also Figure 1(a).

Platinum(II) (2-(p-tolyl)pyridinato- N,C^2') (acetyl acetate) $[Pt(tpy)(acac)]$. 100 mg of $Pt(tpy)(\mu-Cl)_2Pt(tpy)$ dimer, 25 mg of 2,4-pentanedione and 85 mg of anhydrous sodium carbonate were refluxed at 100 °C in 8 ml of 2-ethoxyethanol under inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and filtration yielded crude product that after drying and flash chromatography (silica/dichloromethane) gave bright yellow-green solid (42% yield). 1H NMR (360 MHz, $CDCl_3$), ppm: 8.94 (d, 1H, J 5.9Hz), 7.74 (t, 1H, J 6.8Hz), 7.53 (d, 1H, J 7.8Hz), 7.39 (s, 1H), 7.30 (d, 1H, J 7.8Hz), 7.04 (t, 1H, J

6.8Hz), 6.88 (d, 1H, J 7.8Hz), 5.45 (s, 1H), 2.00 (s, 3H), 1.98 (s, 3H), 1.95 (s, 3H). See Figure 4, compound number 1. See also Figure 1(b).

Platinum(II) (7,8-benzoqionolato- N,C^3') (acetyl acetonate) [Pt(bzq)(acac)]. 100 mg of Pt(bzq)(μ -Cl)₂Pt(bzq) dimer, 25 mg of 2,4-pentanedione and 85 mg of anhydrous sodium carbonate were refluxed at 100 °C in 8 ml of 2-ethoxyethanol under inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and filtration yielded crude product that after drying and flash chromatography (silica/dichloromethane) gave bright yellow solid (27% yield). ¹H NMR (360 MHz, acetone-d₆), ppm: 9.13 (d, 1H, J 5.4Hz), 8.25 (d, 1H, J 8.3Hz), 7.75 (m, 2H), 7.50-7.57 (m, 3H), 7.44 (dd, 1H, J 5.4, 5.4Hz), 5.52 (s, 1H), 2.04 (s, 6H). See Figure 4, compound number 2. See also Figure 1(c).

Platinum(II) (2-benzylpyrinato- N,C^2') (acetyl acetonate) [Pt(bzpy)(acac)]. 100 mg of Pt(bzpy)(μ -Cl)₂Pt(bzpy) dimer, 25 mg of 2,4-pentanedione and 85 mg of anhydrous sodium carbonate were refluxed at 100 °C in 8 ml of 2-ethoxyethanol under inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and filtration yielded crude product that after drying and flash chromatography (silica/dichloromethane) gave bright yellowish green solid (20% yield). ¹H NMR (500 MHz, CDCl₃), ppm: 8.88 (d, 1H), 7.71 (t, 1H), 7.35-7.43 (m, 2H), 7.13 (t, 1H), 6.98-7.02 (m, 2H), 6.91 (t, 1H), 5.49 (s, 1H), 4.16 (s, 2H), 1.96 (s, 3H), 1.95 (s, 3H).

Platinum(II) (2-(2'-thienyl)pyridinato- N,C^3') (acetyl acetonate) [Pt(thpy)(acac)]. 100 mg of Pt(thpy)(μ -Cl)₂Pt(thpy) dimer, 25 mg of 2,4-pentanedione and 85 mg of anhydrous sodium carbonate were refluxed at 100 °C in 8 ml of 2-ethoxyethanol under inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and filtration yielded crude product that after drying and flash chromatography (silica/dichloromethane) gave bright orange solid (20% yield). ¹H NMR (500 MHz, CDCl₃), ppm: 8.78 (d, 1H), 7.67 (t, 1H), 7.46 (d, 1H), 7.26 (d, 1H), 7.17 (d, 1H), 6.86 (t, 1H), 5.46 (s, 1H), 1.98 (s, 3H), 1.95 (s, 3H).

Platinum(II) (2-(2'-(4',5'-benzothienyl)pyridinato- N,C^3') (acetyl acetonate) [Pt(btp)(acac)]. 100 mg of Pt(btp)(μ -Cl)₂Pt(btp) dimer, 25 mg of 2,4-pentanedione and 85 mg of anhydrous sodium carbonate were refluxed at 100 °C in 8 ml of 2-ethoxyethanol under inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and filtration yielded crude product that after drying and flash chromatography

(silica/dichloromethane) gave orange-red solid (20% yield). ^1H NMR (360 MHz, CDCl_3), ppm: 8.90 (d, 1H, J 5.9Hz), 8.75-8.79 (m, 1H), 7.77-7.81 (m, 1H), 7.71 (dt, 1H, J 1.5, 7.8Hz), 7.27-7.34 (m, 3H), 6.95 (dt, 1H, J 1.5, 6.8Hz), 5.54 (s, 1H), 2.08 (s, 3H), 2.01 (s, 3H). See Figure 4, compound number 3. See also Figure 1(e).

5 *Platinum(II) (2-(4',6'-difluorophenyl)pyridinato- N,C^2') (acetyl acetonate) [Pt(4,6- F_2 ppy)(acac)].* 131 mg of Pt(4,6- F_2 ppy)($\mu\text{-Cl}$) $_2$ Pt(4,6- F_2 ppy) dimer, 43 mg of 2,4-pentanedione and 109 mg of anhydrous sodium carbonate were refluxed at 100 °C in 10 ml of 2-ethoxyethanol under inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and filtration yielded crude product that after drying and flash
10 chromatography (silica/dichloromethane) gave bright yellow solid. ^1H NMR (360 MHz, acetone- d_6), ppm: 9.06 (dt, 1H, J 1.0, 5.9Hz), 8.08-8.13 (m, 1H), 8.01 (dt, 1H, J 1.5, 8.3Hz), 7.38-7.43 (m, 1H), 7.05 (dd, 1H, J 2.4, 9.3Hz), 6.69-6.76 (m, 1H), 5.61 (s, 1H), 2.01 (s, 3H), 1.99 (s, 3H). See Figure 4, compound number 4. See also Figure 1(d).

15 *Platinum(II) (2-(4',5'-difluorophenyl)pyridinato- N,C^2') (acetyl acetonate) [Pt(4,5- F_2 ppy)(acac)].* 68 mg of Pt(4,5- F_2 ppy)($\mu\text{-Cl}$) $_2$ Pt(4,5- F_2 ppy) dimer, 36 mg of 2-picolinoc acid and 57 mg of anhydrous sodium carbonate were refluxed at 100 °C in 5 ml of 2-ethoxyethanol under inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and filtration yielded crude product that after drying and flash
20 chromatography (silica/dichloromethane) gave bright yellow solid. ^1H NMR (360 MHz, acetone- d_6), ppm: 8.99 (d, 1H, J 5.7Hz), 8.06 (dt, 1H, J 2.3, 8.0Hz), 7.90 (d, 1H, J 8.0Hz), 7.62-7.68 (m, 1H), 7.37 (tt, 1H, J 1.7, 5.7Hz), 7.20-7.25 (m, 1H), 5.58 (s, 1H), 1.99 (s, 3H), 1.98 (s, 3H). See Figure 4, compound number 6. See also Figure 1(f).

25 *Platinum(II) (2-(4',5'-difluorophenyl)pyridinato- N,C^2') (2-picolinato) [Pt(4,5- F_2 ppy)(pico)].* 69 mg of Pt(4,5- F_2 ppy)($\mu\text{-Cl}$) $_2$ Pt(4,5- F_2 ppy) dimer, 30 mg of 2-picolinoc acid and 52 mg of anhydrous sodium carbonate were refluxed at 100 °C in 5 ml of 2-ethoxyethanol under inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and filtration yielded crude product that after drying and flash
30 chromatography (silica/dichloromethane) gave bright yellow solid. ^1H NMR (500 MHz, CDCl_3), ppm: 9.15 (d, 1H, J 5.6Hz), 9.05 (d, 1H, J 5.6Hz), 8.08-8.21 (m, 2H), 7.89 (td, 1H, J 1.2, 8.0Hz), 7.68-7.71 (m, 1H), 7.54 (d, 1H, J 8.0Hz), 7.32-7.36 (m, 1H), 7.12-7.20 (m, 2H). See Figure 4, compound number 7. See also Figure 1(g).

Platinum(II) (2-(4'-cyanophenyl)pyridinato- $N,C^{2'}$) (acetyl acetate)
 [Pt(cppy)(acac)]. 69 mg of Pt(cppy)(μ -Cl)₂Pt(cfppy) dimer, 58 mg of 2-picolinoc acid and 52
 mg of anhydrous sodium carbonate were refluxed at 100 °C in 5 ml of 2-ethoxyethanol under
 inert gas atmosphere for 15 hours. Cooling to room temperature, addition of cold water and
 5 filtration yielded crude product that after drying and flash chromatography
 (silica/dichloromethane) gave bright yellow solid. ¹H NMR (360 MHz, acetone- d_6), ppm:
 9.07 (dt, 1H, J 1.0, 5.9Hz), 8.14 (dt, 1H, J 1.5, 7.8Hz), 8.05 (dt, 1H, J 1.0, 8.3Hz), 7.77-7.79
 (m, 2H), 7.46-7.50 (m, 1H), 7.43 (dd, 1H, J 1.5, 8.3Hz), 5.61 (s, 1H), 2.01 (s, 6H).

OLED preparation and testing. Polymer blend OLEDs were spun coat from
 10 chloroform solution on patterned pre-cleaned and oxygen plasma treated indium tin oxide
 (ITO) coated glass substrates and covered with vacuum-deposited aluminum(III) tris(8-
 hydroxyquinolate) and/or Mg:Ag (10:1 weight ratio) cathode (500 Å) for the single-layer
 and heterostructure architectures, respectively. Typically, 7.5 ml of a chloroform solution
 contained 100 mg of PVK, 40 mg of PBD and 2.5 mg of (45F₂ppy)Pt(acac). Chosen spin-
 15 coating conditions (3000 RPM, 40 s, Specialty Coating Systems, Inc.) led to 1300±20 Å-thick
 PVK:PBD:dye films as determined by ellipsometry (Rudolph automatic ellipsometer
 equipped with a He:Ne laser). Prior to spinning, the solutions were filtered through a 0.2 µm
 filter. Tris(8-hydroxyquinoline) aluminum (III) (Sigma-Aldrich, Inc) (Alq₃) was sublimed
 prior to use. All measurements on the devices were carried out in air at room temperature.
 20 Device current-voltage and light intensity characteristics were measured using the
 LabVIEW™ program by National Instruments with a Keithley 2400 SourceMeter/2000
 Multimeter coupled to a Newport 1835-C Optical Meter. Electroluminescence spectra were
 recorded at room temperature on a PTI QuantaMaster™ Model C-60SE spectrofluorometer.

Other methods known to those skilled in the art of fabricating OLEDs may be used.

25 While the invention has been described in detail with reference to certain
 embodiments, it will be recognized by those skilled in the art that there are other
 embodiments of the invention within the spirit and scope of the claims.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2
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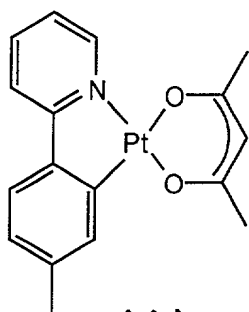
2. The device of claim 1 wherein said metal is platinum.
3. The device of claim 2 wherein platinum is divalent.

ABSTRACT

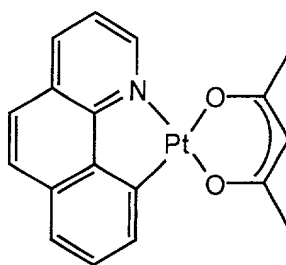
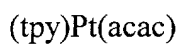
A device for producing electroluminescence comprising an organic light emitting device including an emissive layer comprising an organometallic compound comprised of a metal bound to a single carbon-coordination ligand, with the single carbon-coordination

5 ligand being a monanionic carbon-coordination ligand.

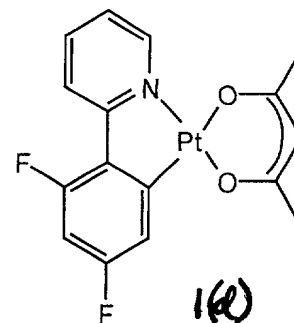
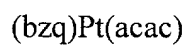
(ppy)Pt(acac)



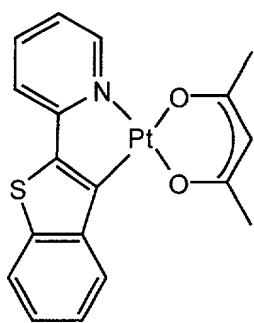
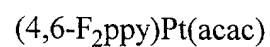
1(b)



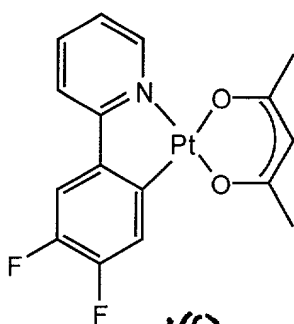
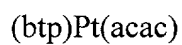
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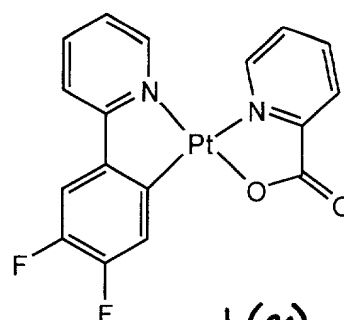
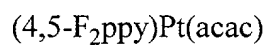
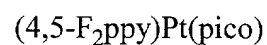
16)



(1e)



1(f)


$$1(q)$$


Figures 1(a) - 1(g)

Figure 2: This Emission spectrum shows the spectra of both Pt(ppy)_2 and $\text{Pt(ppy)}_2\text{Br}_2$. The former gives green emission, partly from MLCT transitions, and the latter gives blue emission, predominantly from a triplet $\pi\text{-}\pi^*$ transition. The structure observed for the $\text{Pt(ppy)}_2\text{Br}_2$ spectrum is consistent with ligand centered emission. The luminescent lifetimes for the two complexes are 4 and 150 μsec .

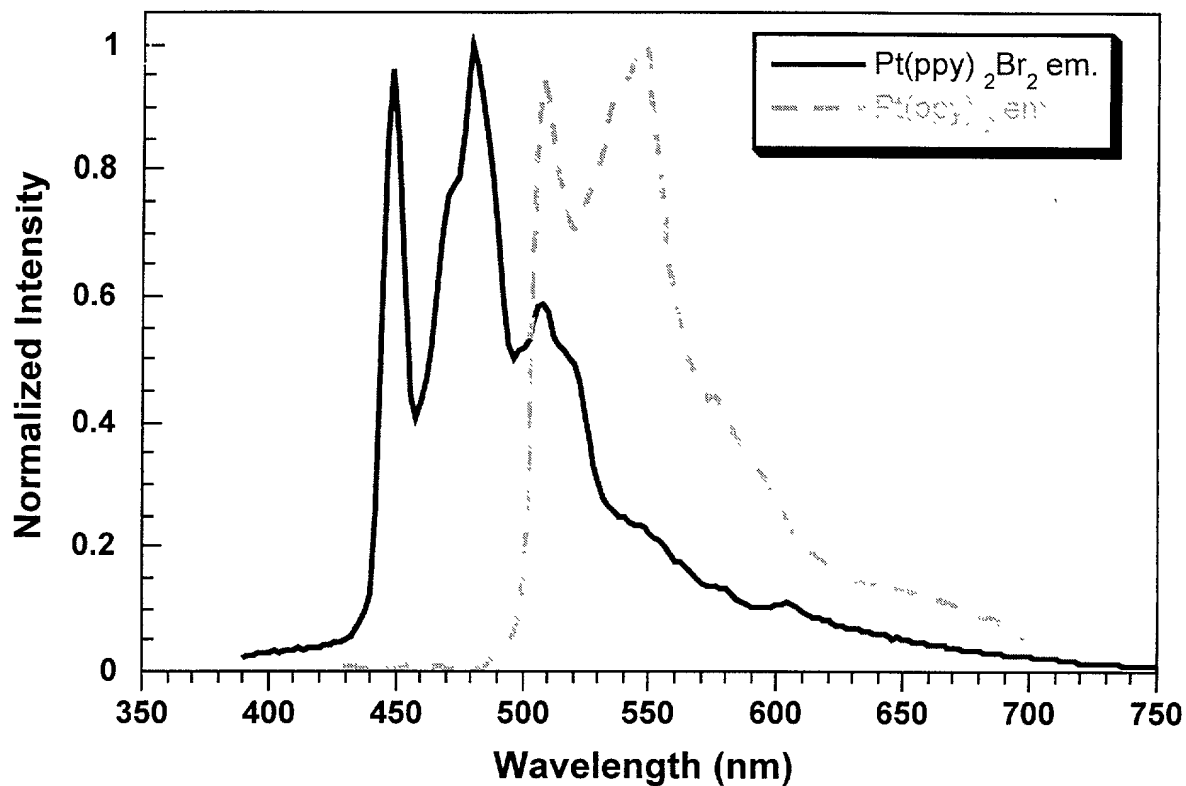


Figure 2

Figure 3: This plot shows the emission spectra of (ppy)AuCl₂ and (ppy)A₂ (2,2'-biphenylene). Both emit from ligand triplet π - π^* transitions.

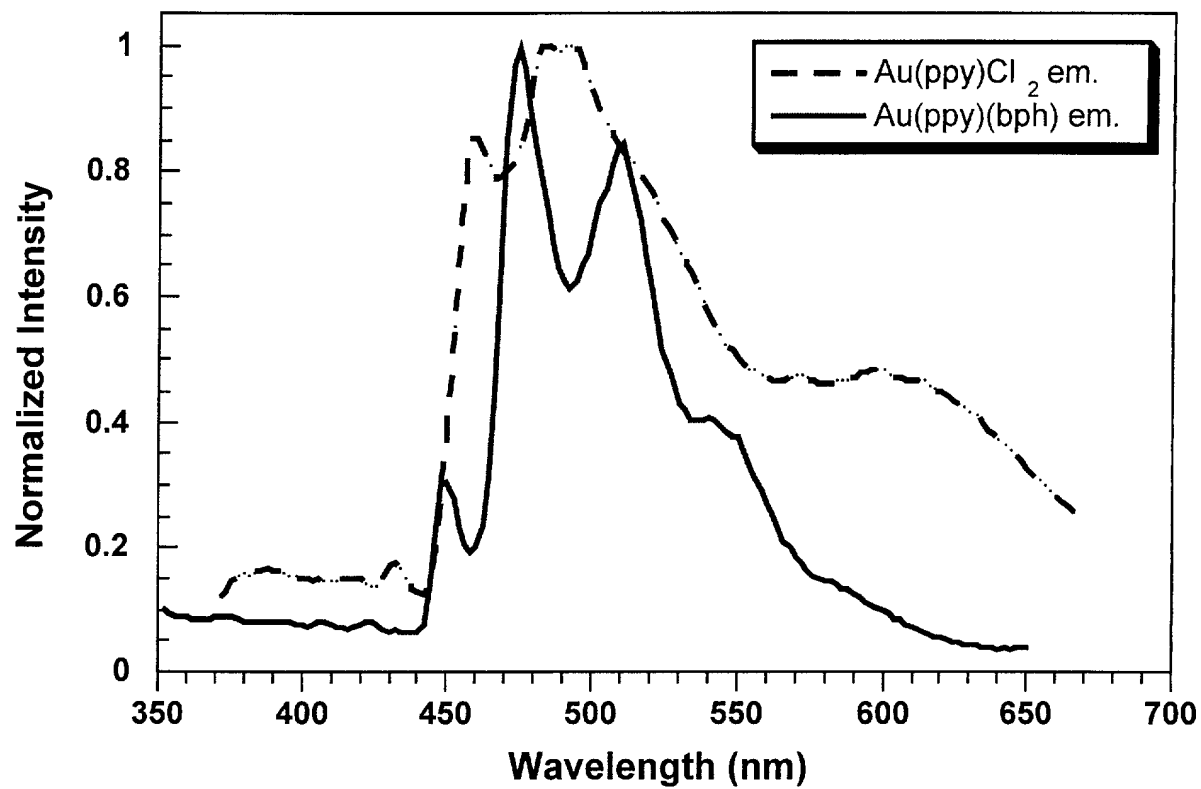


Figure 3

- saturated points
in 10 nm intervals
- ◇ (C-N)Pt(LX)
- ☆ white

x	y	#	C-N
0.21	0.5	1	tpy
0.26	0.56	2	bzq
0.65	0.35	3	btp
0.17	0.29	4	4,6-F ₂ ppy
0.2	0.51	5	ppy
0.23	0.56	6	4,5-F ₂ ppy
0.24	0.62	7	* 4,5-F ₂ ppy-pico
0.26	0.54	8	4,5-F ₂ ppy_EL
0.262	0.608	9	Ir(ppy) ₃
all (C-N)Pt(acac) except *			

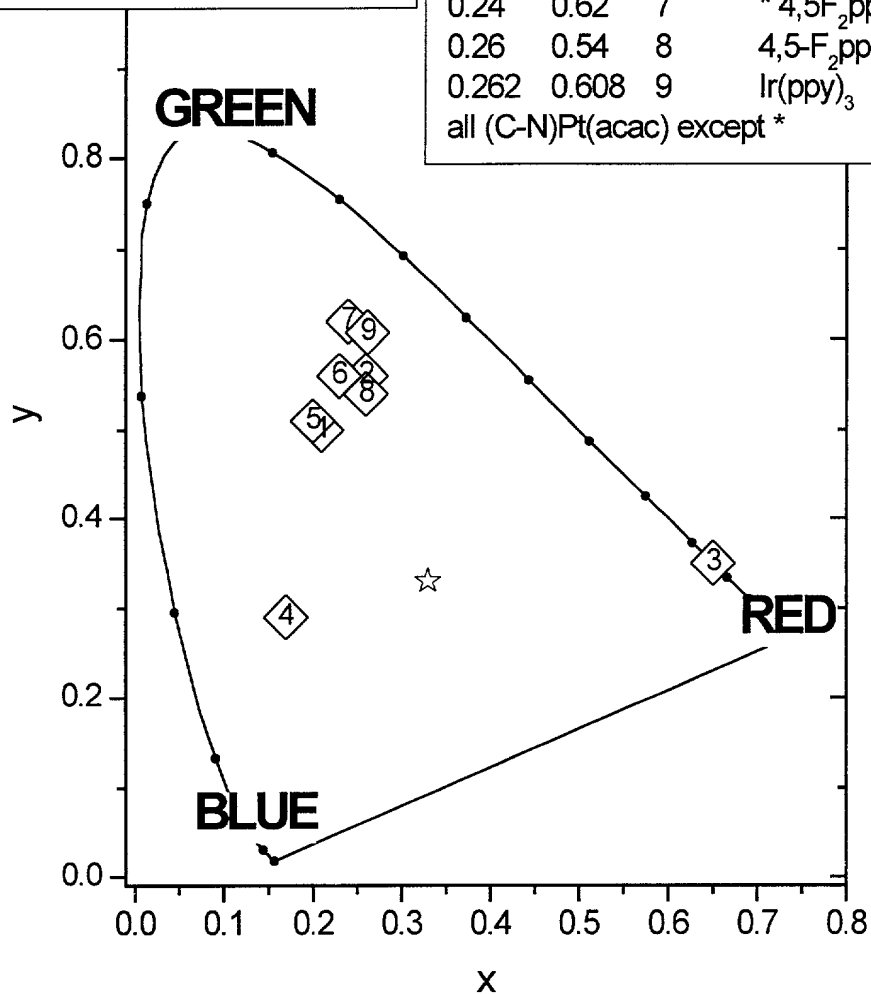


Figure 4

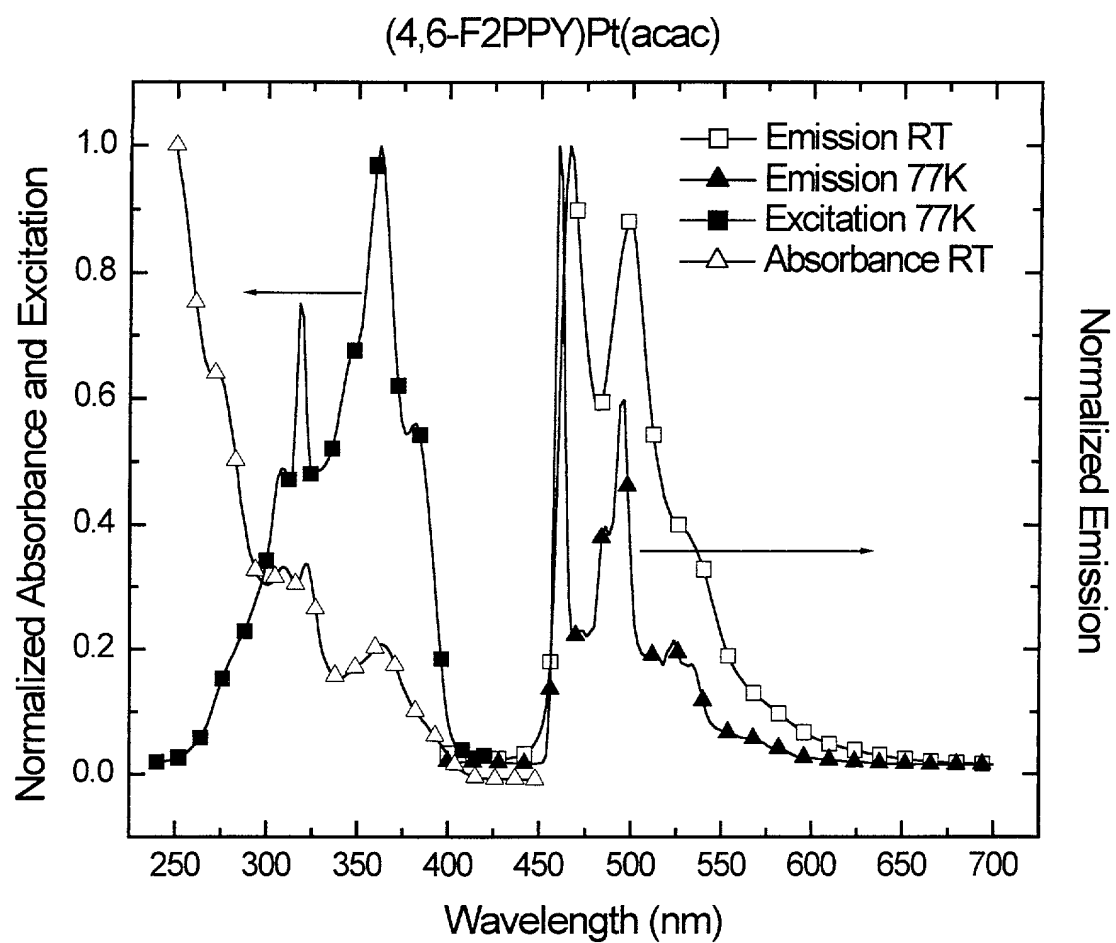


Figure 5

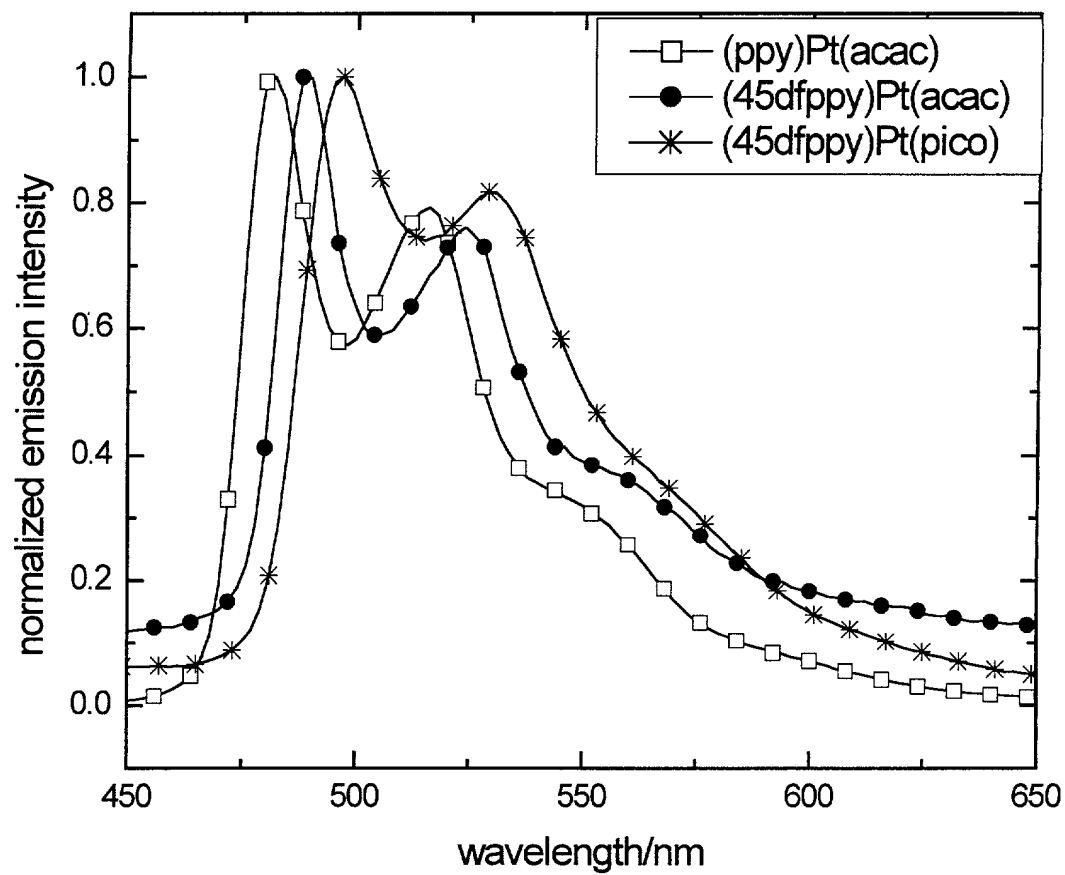


Figure 6

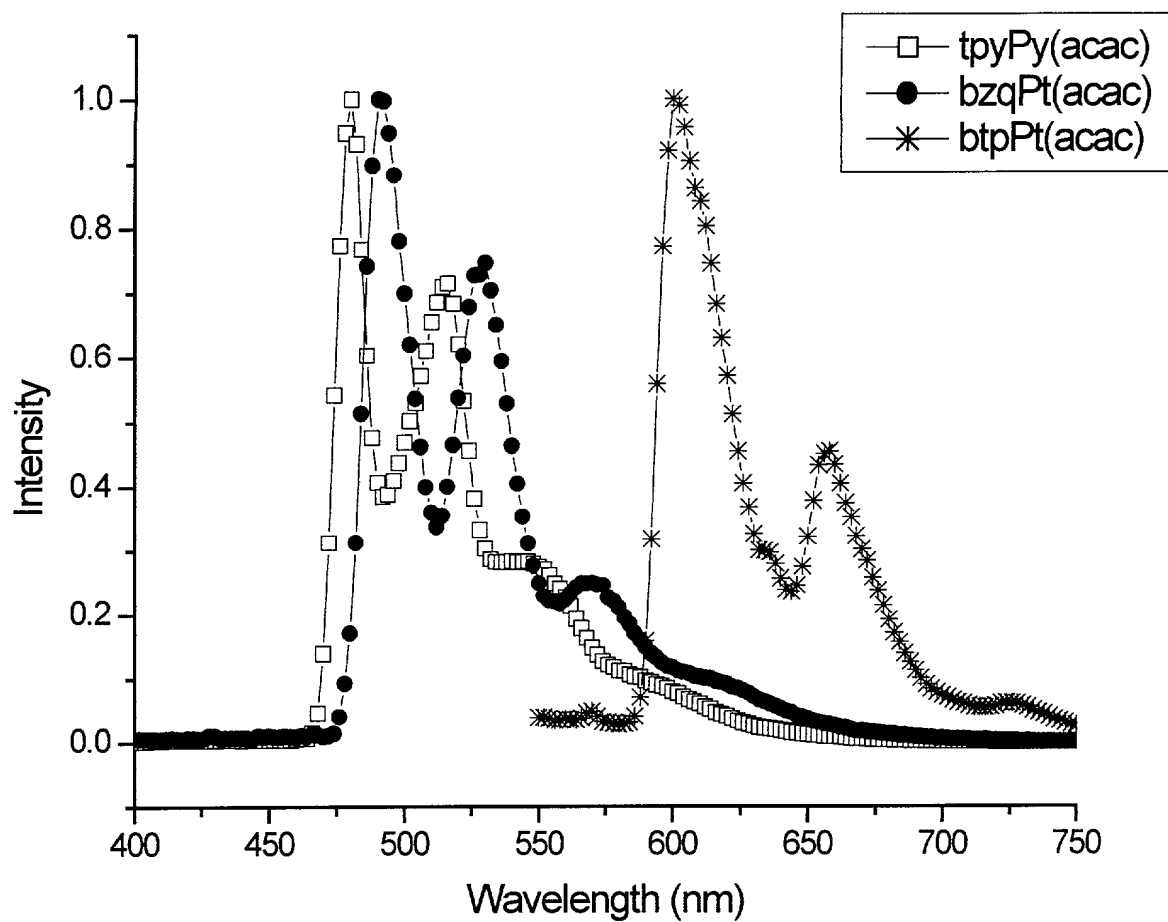


Figure 7

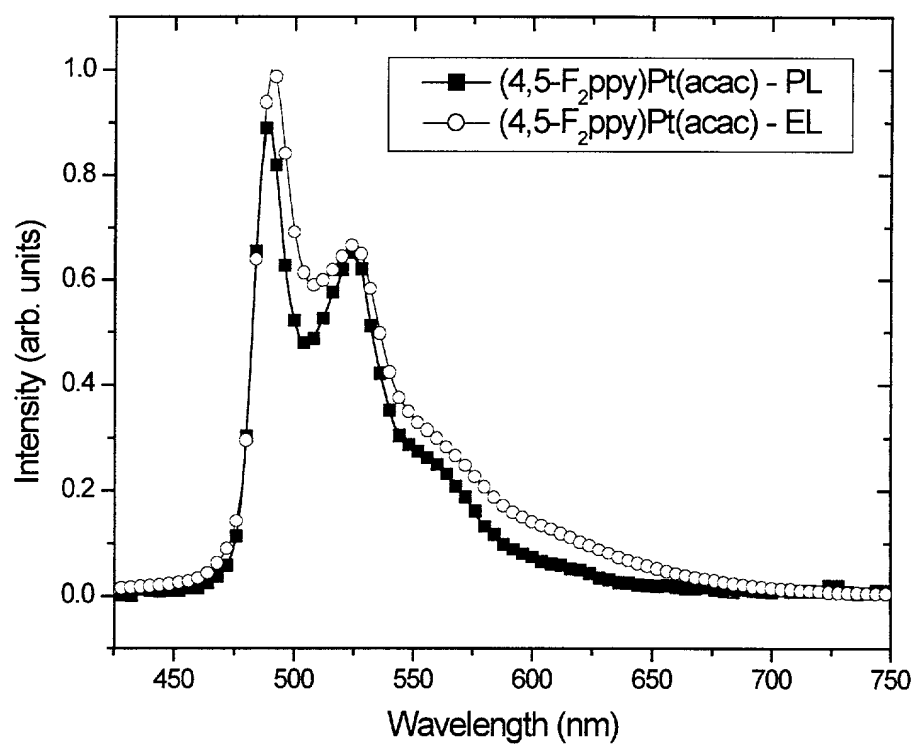


Figure 8

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

DECLARATION

ATTORNEY'S DOCKET NO.
10020/20701

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name,

I believe I am an original, first, and joint inventor of the subject matter that is claimed and for which a patent is sought on the invention entitled **ORGANOMETALLIC PLATINUM COMPLEXES FOR PHOSPHORESCENCE BASED ORGANIC LIGHT EMITTING DEVICES**, the specification of which is being filed herewith.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

SEND CORRESPONDENCE, AND DIRECT TELEPHONE CALLS TO:

THOMAS F. MEAGHER

KENYON & KENYON
One Broadway
New York, New York 10004
(212) 425-7200 (phone)
(212) 425-5288 (facsimile)

I declare that all statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under § 1001 of Title 18 of the United States Code and that such willful statements may jeopardize the validity of the application or any patent issuing thereon.

EL 32754876505

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Signature		Date	

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Signature		Date	